MINIATURE/MICRO-SCALE POWER GENERATION SYSTEM

Field of Invention

The instant invention lies in the field of miniature/micro-scale power generation systems; more particularly, the invention lies in the field of Tesla turbine design for use in miniature/micro-scale power generation.

Background:

The state of the art of miniature/micro-scale power generation systems is rudimentary. Miniature generation systems today largely consist of small refrigerator sized systems that generate power during emergencies, but not at high efficiencies.

Typical miniature systems can be broken down into two categories: fuel cell systems and micro-generation. Fuel cells can be efficient if there is a secondary heat usage; otherwise, it is difficult to manufacture fuel cells that are highly efficient (>50%). Further, fuel cells require a catalyst which is usually a rare earth metal such as platinum or palladium. These materials can be extremely expensive and keep the overall costs of the fuel cell high.

Micro-scale power generation systems have been built in labs. No highly efficient, cost effective manufacturing technique or production line is known to exist at this time for these systems. The systems consist of scaled down traditional combustion turbine designs and/or miniature reciprocating engines. Some of the systems are premised upon the utilization of semiconductor fabrication techniques in order to build to small dimensions. None of these systems have proven themselves commercially viable.

Micro-fabrication techniques utilized to construct MEMS (micro electro mechanical systems) in general have limited themselves to produce MEMS of simple structures, having limited movement of mechanical parts. The limited movement usually does not include freely moving parts. Complex three-dimensional systems with moving parts have not been readily proposed to be manufactured utilizing chemical polish, wafer bonding, etching and the like techniques.

However, as illustrated herein, versions of micro-fabrication techniques such as utilized to construct MEMS, may be effectively used to manufacture miniature/micro/sub-micro scaled turbine/generators of the instant design. Use of such manufacturing techniques to solve problems associated with building complex three-dimensional units of micro-machinery with moving parts, including techniques

wherein the units significantly "self-assemble" themselves, combines fortuitously with versions of a historically obscure and disfavored turbine design. The combination offers surprising compatibility for self-assembly.

The instant invention, contrary to tradition, teaches employment on a miniature/micro/sub-micro scale of an anomalous turbine design for power generation. The Tesla-type turbine, which historically has been referred to as a "curiosity", is taught to be suited for miniature/micro-scale. Features of, even disadvantages of, Tesla turbines on a macro scale are suitable for, and even possibly advantageous for, a miniature/micro/sub-micro scale.

The system of the instant invention is disclosed as an efficient scaleable system, scalable both in dimension and combination. Variable sized power sources could be assembled utilizing the basic turbine/generators. An array/matrix format could be structured to employ unitary inlet and exhaust channels, as well as built-in heat recovery and secondary cycle capabilities, so that overall efficiencies of the system could be raised.

In summary, the invention discloses a miniature or micro-scaled Tesla-type turbine design, and associated generator, adapted for efficient small scale operation as well as high volume production techniques, including a design that lends itself to real-time control and dispatching systems, and which might include an array/matrix of turbines, permitting the utilization of efficiency improvement techniques. It is foreseeable for essentially an entire system to be fabricated from generally the same material (silicon-carbide).

Summary of the Invention

The invention comprises a miniature/micro scale Tesla-type gas turbine and associated generator that generates less than 1 horsepower, at least singly, when not matrixed or arrayed together. The impelling fluid could be liquid, but is typically gas. (Inter disk spacing is typically larger for liquids.)

The term "miniature/micro" is used herein to indicate a size ranging from centimeters to sub micron. This is opposed to a range of a meter or larger, which would be referred to as macro scale. The turbine includes at least one chamber having a fluid inlet and a fluid outlet and a source of pressurized fluid, preferably combustion gas, in fluid communication with the inlet. A set of disks, preferably 3 or more in parallel, are journaled for rotation in the chamber, the disks preferably having a diameter of less than 10 centimeters. In some embodiments, the diameter could be 1

centimeter or less. An inter disk spacing is preferably defined between the disks of less than 1/10th of a diameter and in some embodiments of less than 1/20th of a diameter, or even smaller. The interdisk spacing may be .1 mm or less. Experience indicates that such spacing, of .1 mm or less, promotes laminar flow.

The chamber and disks are structured in combination such that fluid from an inlet radially traverses an inter disk path, preferably entering tangentially to a disk set's peripheral edge and exhausting centrally to a disk set. Preferably the fluid exhausts nonturbulently through a substantially unobstructed central area. The absence of a shaft, and a noncentral disk attachment arrangement, furthers such nonturbulent exhaust.

The turbine/generator may include a generator with a set of conducting regions and a set of opposing magnetic regions, each set located upon an element that moves with respect to the other, preferably each set located upon one of a chamber wall or an opposing rotating disk, for simplicity of structure and efficiency.

Disks of a set that function as vanes in a Tesla-type turbine are usually flat and attached together in parallel. However, the disks could be curved or bent, all or in a portion, and could have protrusions. Disk edges may be further modified to direct gas flow. Alternatively, disk edges may be designed to collect energy of a gas striking a disk edge. Inter disk movement of fluid, characteristic of a Tesla-type turbine design, is preferably radially out to in, following a spiral pattern, although more complex movements could be possible. Disks may contain protrusions. Disks in a set may be attached by elements that also function as vanes.

Brief Description of the Drawings:

The foregoing description of preferred embodiments of the invention is presented for purposes of illustration and description, and is not intended to be exhaustive or to limit the invention to the precise form or embodiment disclosed. The description was selected to best explain the principles of the invention and their practical application to enable others skilled in the art to best utilize the invention in various embodiments. Various modifications as are best suited to the particular use are contemplated.

Figures 1 illustrate a turbine on a miniature scale. The scale is in inches. Figure 1 illustrates a side view, figure 1A illustrates a cutaway side view, figure 1B illustrates a top view and figure 1C illustrates a side view of the turbine, and disks.

Figures 2 A and 2B illustrate a micro scale turbine. Figures 2A and 2B illustrate side views of the turbine portion. The figures are not to scale visually, and are not to scale between the horizontal and vertical directions. The difference in scale facilitates visual representation.

Figures 2C and 2D illustrate a turbine disk with side and/or edge protrusions.

Figures 3, including figure 3 A, figure 3 B and figure 3 C, represent a preferred embodiment of a generator design.

Figures 4 - 7 illustrate features of casing designed for a micro turbine/generator. Figures 4 - 7 are not necessarily to scale visually or in the horizontal vs. vertical directions, for ease of visual representation. Figure 4 illustrates casing design. Figure 5 illustrates fuel and air intake as well as exhaust. Figure 6 offers a top view of a micro turbine disk. Figure 7 offers a view of a micro turbine/generator footprint.

Figures 8 and 9 illustrate the matrixing of turbine/generators in an array. Figure 8 illustrates an energy matrix with input and exhaust channels. Figure 9 illustrates a micro turbine/generator matrixed with an air input plane and an air exhaust plane matrixed into the array.

Figure 10 illustrates a top view of a wafer indicating a manufacturing array for micro turbine/generators.

Detailed Description of the Preferred Embodiments:

Design of Miniature Tesla Turbine/Generators:

Tesla-type gas turbine designs as disclosed herein may be regarded as versions of, and/or improvements to, an original Tesla turbine designed by Nicoli Tesla in the early 1900's. That Tesla turbine design has not enjoyed significant commercial exploitation. If treated at all in text books, the Tesla turbine is referred to as a "curiosity." The disadvantages of a Tesla design vis-à-vis other turbine designs includes the fact that Tesla turbine efficiency increases with a reduction in the inter disk spacing between the disks. Tesla designs for turbines have been somewhat of an anomaly historically and largely ignored in gas turbine studies.

One aspect of the instant invention teaches that such a prior anomalous or curious design on a macro scale can have advantages in the field of miniature/micro scaled turbines. One Tesla design disadvantage on a macro scale, namely the increase in efficiency of the design with the decrease in inter disk spacing, could become an advantage on a miniature or micro scale. Further, manufacturing techniques on a

micro scale, in particular stereo lithography and chemical deposition, can maintain excellent control of horizontal dimensions (<1um) over near macroscopic (>1cm) dimensions. Maintaining tolerances when scales change by factors exceeding 10,000 is extremely difficult with traditional means scaled manufacturing techniques.

A miniature/micro scale Tesla-type turbine of the instant design involves a disk type turbine, nominally employing flat disks, which design can enable the creation of extremely flat turbine/generators, having miniature/micro fabrication and array/matrixing advantages.

Figures 1 and 1A-1C illustrate a prototype miniature scaled Tesla turbine. The scale units of the prototype are in inches. Turbine housing 1 includes horn mount 10 with chamber 20 for the receipt of pressurized fluid, preferably air. Air enters through chamber 20, thence through gas port element 17 and into a 90 degree horn 14. The pressurized air in horn 14 exits port 21 peripherally to disks 2. The pressurized air enters tangentially to the set of disks 2, which together with disk base 3 and disk top 7 are journaled for rotation within turbine housing 1. Arrow 18 in figure 1B illustrates the spiral movement of the pressurized air, which could be any pressurized fluid, in the turbine housing and within the inter disk spacing. Figures 1A and 1C illustrate the inter disk spacing defined by disks 2 as well as between disk base 3 and disk top 7. Pressurized fluid spirals from a periphery of the disks 2 to an exhaust cavity at the center of the disks, illustrated by arrow 18 in figure 1B. Pressurized fluid exits the turbine in a direction of arrow 19, shown in figures 1A and 1C.

Figure 1C illustrates inter disk spacing for a miniature turbine. The disks of the miniature turbine are a 0.05 inches thick. Spacers 5 with connecting rods 6 maintain the disks in spaced relationship. The radius of the disks, r_1, as indicated in figure 1C is approximately one inch, and the radius of the exhaust is approximately one fifth of that amount.

Figure 1A illustrates a lower bearing shaft 4 and upper bearing shaft 8. Lower bearing shaft 4 extends within lower bearing 9. Upper bearing retainer 12 retains upper bearing 11. Bottom horn spacer 13 lies between horn 14 and horn support 16. Horn support 16 and horn spacers 15 and 13 help adjust the location of the horn to provide input fluid or gas.

Figures 2A and 2B illustrate a micron sized turbine and generator. (Note that Figures 2A and 2B utilize different and/or varying vertical and horizontal dimensional scales, for representational ease.) Targeted dimensions are indicated on Figure 2A; if

the target proves difficult to achieve in practice or in mass production, the illustrated scale may not be a preferred production scale.

Figures 2C and 2D illustrate a turbine disk D having surface protrusions PR and/or edge protrusions DE.

An aspect of one preferred micro design, indicated by the scale of Figure 2A, is the entire disk set being kept as flat as possible. This means that a favorable ratio of material structure thickness to the strength of the material (such as exemplified by silicon carbide) should be taken into account in the design. In one preferred design, illustrated in Figure 2A, the overall dimension of a generator and turbine could be approximately 250 microns thick with the other dimensions being 1-cm by 1-cm.

Preferred embodiments of a Tesla turbine for the instant invention are designed for maximum single cycle efficiency. One preferred design utilizes 5 individual turbine disks D, although 3 disks may suffice. In the micro turbine design of Figure 2A each disk is shown 7 microns thick and spaced 7 microns from the next disk. This extremely thin and small inter disk spacing may be possible, and cost effective, through using semiconductor fabrication techniques.

Figure 2A illustrates a side view of a micro turbine generator with a turbine stalk ST. A portion of the micro generator illustrated includes top T and bottom B. Vertical scale is indicated to the right in the drawing, (which again is not consistently to scale). Horizontal scale is indicated at the bottom. Visually, neither the vertical scale nor the horizontal scale are fully consistent, for representational ease. Five disks D are indicated as attached and located within the micro turbines MG. Each of the five central disks D has a thickness of approximately seven microns. The inter disk spacing is also approximately seven microns. A spacing of 25 microns is indicated between the upper and lower disk of the set of five disks D and a top disk DT and a bottom disk DB. Such larger inter disk spacing may be advisable in order to control any heat generated in the turbine, so as not to affect the generators. Top disk DT and bottom disk DB are indicated as having implanted magnetic north and magnetic south portions. Pressurized fluid, as indicated by arrow 18, enters the inter disk spacing between the five disk set in accordance with arrow 18. Although not indicated on drawing 2A, disks D may be attached to stalk ST by spokes SP at the center region as in figure 6. Such spokes would permit pressurized fluid, entering from the direction of arrow 18, to exhaust from the disks at a central area, as indicated by arrow 19. Top portion T and bottom portion B each have conducting elements C opposing magnetic

elements MN and MS located along rotating turbine disks. The turbine is journaled for rotation of stalk ST within cavity CA of bottom section B and top section T.

Between each of the Tesla disks some air flow impediments, including structural elements and possibly extra protrusions, may be placed. See for instance elements 5 and 6 of Figures 1A and 1C of the prototype. These impediments may serve two roles. First they can serve as what Tesla referred to as air buckets, which catch air or gas and require it to go around the impediment. Secondly, they can attach together and help create rigidity between individual disks so that each disk can be thinner. Overall, small disk spacing and thinness of the disks can be valuable in a design from an efficiency standpoint.

Tesla taught in his original patent that a Tesla-type turbine works off of two primary physical effects. The first is a surface cohesion of the air or gas moving between the disks. In todays language this is a zero slip boundary layer. In this regard, the disks should be preferably extremely tightly coupled, which improves the overall efficiency of the turbine. Secondly, Tesla taught that turbines work off of directional air flow and the conversion of the velocity of the air flow into the physical movement of the turbine. Therefore, gradual changes in the velocity of the air or gas more effectively extract the energy within the system. To this extent, it is preferred for an overall ratio between the inner and outer diameter of a turbine disk to be great. Preferably air or gas flows from a disk peripheral area inwardly, radially, toward the disk center, as illustrated by arrow 18 in Figure 1B, and exhausts through a center region of the disk, as illustrated by arrow 19 in Figure 1A. Thus, air or gas preferably flows within the Tesla turbine in a centrifugal fashion. This centrifugal air flow helps ensure that there is a gradual change in flow and allows the turbine a maximum time to extract energy out of the flow, since the air or gas on the outer portions of the disk is moving at a much higher velocity than the air or gas at the center of a disk. The relative linear velocity between the inlet and exhaust locations on the disk is generally given by r_1/r_2 where r_1 is the radius of the disk and r_2 is the radius of the exhaust port. Therefore, the greater the differential between the inner and outer diameter of the turbine disk, the greater the potential velocity differential. This velocity differential has a direct correlation with the efficiency of the turbine. Further, in order for a high velocity change to not build up pressure in the turbine, the input and output ports should be sized accordingly. By combining a maximum inner/outer diameter ratio

with properly sized input/output ports, preferred basic dimensional ratios of a Tesla turbine can be derived.

Manufacturing Possibilities – High Volume Processes:

Tesla turbines are three dimensional structures preferably having closely spaced parallel disks or plates functioning as vanes. Nozzles may be incorporated into the design for directing fluid flow through the vanes, (that is through the inter disk spaces) from outside to inside, exhausting through a central region of the disks or an upper and/or lower region, generating the rotational forces acting on the turbine. The closer the plates are spaced the greater the efficiency of the turbine in transferring the energy of a rapid and/or expanding gas into rotational forces.

Such Tesla turbine design is suited for miniature and/or micro-fabrication techniques, such as planar manufacturing processes, where a horizontal spacing of features can be tightly controlled to extremely small dimensions. Potential benefits of a combination of MEMS (Micro ElectroMechanical Systems) with Tesla turbine manufacture exist.

The use of filler material and support material, independently removable to create a freestanding object, has not been widely practiced in micro fabrication. However the removal of filler material followed by an etch or dissolution of support material could allow a turbine of the instant design, which turns freely within a casing, to be essentially "self-assembled".

Alternately, the use of a web process for the instant turbine construction is possible. Web processes have generally been considered for manufacturing essentially two dimensional objects, such as band-aids, newspapers or adhesive labels. (While these examples are strictly speaking three dimensional, they can be regarded as two dimensional.) Although the use of a web manufacturing process has not hitherto been considered a suitable manufacturing process for creating a three dimensional object such as a turbine, the instant design may be an exception. Further, the concept of screen-printing a generator has not been fully appreciated. Screen-printing conductive materials is an emerging area. Screen-printing magnetic particles has not been practiced on practical scale. The combination of the two processes, web and screen printing, is possible for the creation of a turbine and generator according to preferred embodiments herein.

Illustrated Fabrication of Turbine/Generator - MEMS

One possible method of fabrication for an embodiment for the instant system, enhancing its practicability, teaches utilizing semiconductor fabrication techniques. Ideally, for these purposes, the shape of the turbine would be essentially flat and have a width to height ratio of at least 10X. Figures 2A and 2B illustrate views of portions of possible turbine and generator designs.

One possible micro fabrication technique for turbines and generators could utilize two wafers. Each wafer could have multiple partial turbines/generators G, as indicated in Figure 10 (top view of an entire wafer W). The binding of the two wafers together could create the individual power sources.

Actual feature dimensions of preferred micro turbines and generators are much larger than the feature dimensions of that utilized in semiconductor chips. Today's feature size capabilities of semiconductor fabrication equipment is about 0.18 micron. The smallest feature size envisioned for the preferred turbines and generators of the instant invention is likely approximately 1-2 microns. Therefore, the instant turbines and generators would require approximately an order of magnitude less in feature tolerances, a manufacturing benefit.

To continue the illustration in more detail, one fabrication process, illustrated in Figure 2B, could begin with a substrate S. The substrate's actual height is not necessarily relevant, but one of its sides should be a polished surface which is extremely flat and smooth. The fabrication process would preferably be broken down so that two unique planes are created. Each plane could then subsequently be bonded together so that a full power source is created. Figure 2B illustrates only one plane.

A turbine and generator could be "self assembled" by removing, subsequent to bonding, "support structure" SS utilized to hold individual planes together during processing and bonding. Such "support structure" could be removed by either chemical dissolving or chemical/heat dissolving, for instance.

One possible fabrication process could include utilizing four different types of structures: turbine/casing structure TCS; electric generator structure GS; filler structure FS; and support structure SS. A combination of the use of these structures could enable the fabrication of a micro turbine and generator. The selected and independent removal of the filler FS and the support structures SS could enable a turbine and generator to have free motion within a system that was built as a single unit, without the assembly of each individual structure separately.

A top plane of a turbine and generator and a bottom plane of the turbine and generator could have different processing steps, since each is trying to build different parts of the power source. For purposes of illustration, a bottom plane could be a plane that includes a base, half of a power transmission grid, and turbine/generator stalks and chamber walls, as illustrated in Figure 2B. The bottom plane could also include portions of combustion chambers, air intakes, exhausts and nozzles, arranged for effective matrixing. A top plane, not specifically illustrated herein, could contain the other portions of such elements, including continuing portions of the power transmission grid, exhaust grid and fuel supply.

Figures 3A – 3C illustrate an electric generator design for coupling to a turbine drive. Figure 3A illustrates the placement of conducting elements C and their interconnection, as is known in the art, for electric power output. Elements C are illustrated affixed to bottom B or top T. Figure 3 B illustrates the arrangement of magnetic portions MN and MS, alternately polarized as magnetic north or magnetic south.

Figures 4 – 9 illustrate how individual turbines and generators of the instant design could be matrixed, utilizing arrayed air intakes and exhausts. Starting with the individual unit, Figure 4 illustrates a casing design for a micro turbine/generator. (Note that figure 4 is drawn with differing horizontal and vertical scales, which was done for ease of representation.) Figure 4 illustrates the placement of exhaust port's EP and input nozzles IN suitable for a micro turbine and generator, as per figures 2A and 2B. Figure 4 also illustrates a combustion chamber CC containing glow line GL, which is a hot wire or high resistant wire for combustion ignition.

Figure 5 expands upon figure 4. Figure 5 illustrates unitary exhaust shafts E in communication with exhaust ports EP. Figure 5 illustrates unitary air intake conduits A in communication with combustion chambers CC which output into input nozzles IN. Figure 5 illustrates the placement of fuel lines FL. for feeding into combustion chambers CC.

Figure 6 is a top view of a micro turbine MG in relation to the fluid input nozzles, and figure 7 is a view of a micro turbine footprint. Indicated in the top view of the micro turbine in figure 6 is stalk ST connected by spokes SP to disk D. Arrow 18 indicates the movement of air or other pressurized fluid through the input nozzles to the central exhaust.

Figure 8 illustrates an energy matrix. Single cycle turbine generators are presumed to be distributed within the matrix. Figure 8 illustrates the use of unitary air conduits A and exhaust conduits E to supply an arrayed matrix of generators. Figure 9 illustrates an energy matrix having an air input plane AIP and an air exhaust plane AEP attached at opposing ends.

The basic steps that could be utilized in the fabrication of a bottom plate and turbine are preferably chemical etch, chemical/physical vapor disposition, lithography, photoresist spin & development, annealing, and wafer cleaning/solvent cleaning. Deposited filler material and support structure could be selectively utilized to produce freely moving parts. The combination of such steps, as is known in the art, along with depositing different materials and the utilization of different masks, could enable an entire fabrication of a turbine/generator plane.

Once a top plane and a bottom plane are fabricated, the next step would be to remove the filler material utilized during the fabrication of the individual planes. The filler material is utilized in the development of the planes to create the three dimensional structures that are required in the turbine and generator. This filler material is ideal when utilizing a deposition technique where a gap needs to exist and the deposition process would otherwise fill the gap. If a filler material is utilized, the gap is filled with this material which enables a deposition process to be utilized. The filler material is removed from both the top and bottom planes by utilizing a simple dissolvent solution. The wafers are bathed in this solution for a period of time such that all of the filler material is then removed.

An independently removable support structure assists “self assembly”. Self-assembling indicates that two individual planes are bonded together where the planes consist of rigid structures. The rigid structures are subsequently processed to allow free movement.

Fabrication of three dimensional structures with moving parts, such as a turbine, typically requires a “pick and place” method to install the moving parts into the casing. It would be preferred to avoid or minimize pick and place steps. Thus, a preferred method would be to hold moving parts in place until the entire power source is assembled. A “self-assembly” method utilizing “support structure” eliminates pick and place requirements. The support structure acts as a holding method for the moving parts until the turbine and generator is assembled. Once an entire wafer is fabricated and assembled with another wafer, a process of removing the support

structure makes the process a self-assembly process. The support structure is made of a material resistant to dissolving in the dissolvent utilized for the filler material. The support structure, however, should remain dissolvable after repeated annealing cycles.

In the fabrication steps of a top plane and a bottom plane, there could be requirements for metallic inserts into a silicon carbide structure or the like in order to create a stator/rotor electric generator system. Metallic inserts on turbine disks themselves, as illustrated in Figure 3B, are preferably magnetized. The magnetization of inserts could be accomplished as a processing step during building of a plane. Once an entire plane is built, it might be more difficult to magnetize individual magnetic inserts. All of the magnetic inserts on an entire wafer would preferably be magnetized at once. This preferably entails utilizing a template in which a current wafer is input and a magnetization step is then run for the wafer.

To summarize, possible steps of a fabrication process for a turbine and generator of the instant design are:

1. Polish substrate wafers for both a top and a bottom plane.
2. Process the top and bottom plane individually utilizing their individual fabrication steps, including a magnetization step if desired.
3. Prepare surfaces for wafer bonding.
4. Remove filler material from the top and bottom planes.
5. Align top and bottom planes and press together.
6. Wafer bond top and bottom planes to create a wafer of power sources.
7. Remove support structure material from the power sources.

Illustrated Fabrication – Web Process

Alternately, in a web processing method, continuous strips of material could be used to form turbine rotating disks and fixed top bases and bottom bases, as well as spacers. The thickness of a strip would probably be 0.5mm or less. The width would at least be as great as a turbine diameter. The bonding of the individual strips would allow creation of 3 dimensional structure.

Tractor holes in a strip could allow alignment for the processing steps and the subsequent bonding steps.

A resist layer could be used to protect a metal strip during an etching process to create raised features on a flat surface. Etching could create, for instance, a bushing which would support the turbine disks and be a contact point to the housing. In addition shafts could be formed on the flat surfaces.

For a Tesla turbine, attachment elements joining individual plates could be simply shafts. The shafts can also collect energy from an accelerated and/or pressurized fluid which causes the disks to rotate.

A magnetic material could be deposited in the form of a paste to create a generator. The paste could consist of fine magnetic particles in an appropriate carrier. Further steps could include: sintering magnetic material; inducing the material to the appropriate polarity with alternating North/South poles around each turbine; and punching a center exhaust.

A plurality of the above web pieces could mate using the turbine shaft/vanes, and the turbine plates could be aligned to each other using the exhausts or the outer edges. Once the web pieces were appropriately aligned, they could be permanently welded, which would result in a completed turbine.

Bases could be constructed in the same fashion as turbines. A continuous strip of material would be selected. The thickness would be sufficient to support the forces generated by the turbine. Tractor feed holes could be punched, and a center exhaust also punched. Resist could be deposited to protect areas where etching is not desired. After etching one could remove resist. This process would create the other half of the bushing on which a turbine would rotate. Appropriate generator coils could be screen printed. Contacts also could be screen printed. Preferably one would include a spacer construction, which is a composite of individual layers which results in the necessary height to contain the turbine and generator structures.

A complete turbine casing (base, spacer, lid) could be similarly created and assembled on this base.

The final assembly could entail a process similar to lamination. One major difference would be that the turbine must be picked and placed into the bushing on the base. Also when the lid is attached the bushing between the turbine and lid would have to be aligned.

The word "a" as used in the claims below refers to at least one.

A "set" means a plurality. Typically a set of disks are sized and structured to be essentially identical, although that is not per se necessary.

An inter disk space is the space defined, in general, between two disks. Its key dimension is the distance, in general or for practical purposes, between two disks.

Usually disks are attached in parallel, but exceptions could be made without destroying the effectiveness of the system.

The foregoing description of preferred embodiments of the invention is presented for purposes of illustration and description, and is not intended to be exhaustive or to limit the invention to the precise form or embodiment disclosed. The description was selected to best explain the principles of the invention and their practical application to enable others skilled in the art to best utilize the invention in various embodiments. Various modifications as are best suited to the particular use are contemplated. It is intended that the scope of the invention is not to be limited by the specification, but to be defined by the claims set forth below.